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Technological and Economic Dynamics

Modeling Uncertainty

Evolution of Cooperation

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Options is a journal featuring the activities of the International Institute for Applied Systems Analysis (IIASA), located in Laxenburg, Austria. IIASA is an interdisciplinary, non-governmental research institution sponsored by a consortium of National Member Organizations in 17 nations. The Institute's research focuses on sustainability and the human dimensions of global change. The studies are international and interdisciplinary, providing timely and relevant information and options for the scientific community, policy makers and the public.

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EDITORIAL

IIASA hosts more than fifty workshops, conferences and other meetings each year. In this issue, *Options* highlights the Systems Analysis of Technological and Economic Dynamics Project, with ideas from some of the Project's recent workshops, and includes a feature on biological cooperation inspired by an IIASA workshop on the Evolution and Ecology of Mutualism.

Workshops organized by the Institute can serve many different purposes: presenting IIASA's results to a broad audience and soliciting feedback, bringing together experts whose ideas can stimulate future research directions at IIASA, and assessing the state of knowledge on a particular subject. Some workshops, which are not always held at IIASA, are jointly organized with other organizations. This was the case with the Joint Symposium of the Canadian Institute for Advanced Research (CIAR) and IIASA called "Modern Perspectives on Economic Growth," held in Ottawa, Canada, in March 1995.

Laxenburg Castle - home of IIASA

Sometimes IIASA hosts meetings at the request of other organizations, as in April 1995, when IIASA scholars and others made presentations at a gathering initiated by the United Nations University. In March 1995, IIASA organized an important workshop funded by the Austrian Ministry of the Environment and the United Kingdom Department of the Environment on the experience of countries in Central and Eastern Europe with international financial instruments directed at improving environmental quality. The workshop results, together with a related IIASA study, will provide important information for the conference of European Environment Ministers to be held in Sofia, Bulgaria, in October 1995.

Of course, IIASA scholars also often participate in conferences and workshops organized by other institutions. In this issue we describe our presence at the annual meeting of the American Association for the Advancement of Science (AAAS) in Atlanta, USA, in February 1995. In June 1995, a number of past, present and future IIASA scholars attended the First Open Meeting of the Human Dimensions of Global Environmental Change Community at Duke University, North Carolina, USA. This international gathering was a milestone, providing clear evidence that there is indeed an outstanding, broad community carrying forward very interesting research on the human dimensions of global environmental change, including work on institutional development, integrated assessment modeling, land use change, property rights and vulnerability. All of these topics and more are at the core of IIASA's work on global change, and the Duke meeting showed clearly that the Institute is a recognized member of this international, interdisciplinary research community.

Dr. Jill Jäger
Deputy Director for Programs

In this issue, we also introduce a lecture series on important new scientific inquiries and approaches, named in honor of the late Professor Tjalling Koopmans, an IIASA alumnus and Nobel prize winner in Economics. In 1995, seven lectures for the general public entitled "Evolution and Complexity" are being held. The first lectures attracted large audiences from within and outside IIASA to hear about topics that are not specifically in IIASA's current research agenda, but should interest us all and may provide new perspectives on current and future research.

Dr. Jill Jäger

Technological and Economic Dynamics

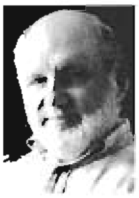
Economists are turning to the general concept of evolution to understand economic change.

Ideas from biology have interested economists at least since Alfred Marshall began using the term "biological conceptions" in 1907. Increasingly, some economists are turning to the general concept of evolution, if not all the particulars of biological evolution, to answer macroeconomic questions about differences between national economies, how economies change, and how technologies move from country to country and industry to industry; and microeconomic questions about how firms arise, grow, compete and eventually die. From this evolutionary perspective, large-scale features of economies emerge from the interactions among firms and industries.

IIASA's Systems Analysis of Technological and Economic Dynamics Project (TED) attempts to answer such questions from this evolutionary perspective. Four broad branches of the project—Learning Processes and Organizational Competence; Technological and Industrial Dynamics; Innovation, Competition and Macrodynamics; and Methodology and Modeling—aim to construct a theoretical basis for a better understanding of economic change, both empirically and with the help of formal models. TED has sponsored several IIASA workshops during the past two years designed to contribute to an evolutionary perspective in economics. The workshops were designed to bring together economists, historians and organizational theorists from around the world for presentations and discussions of ongoing work. In the meetings, the field of evolutionary economics itself evolves as participants share perspectives, arguments and refinements. In the following sections, TED researchers offer an introduction to each branch of the project and share insights from three recent workshops. ■

The Authors

Sidney Winter
"Learning Processes and Organizational Competence"



Giovanni Dosi
"Technological and Industrial Dynamics"

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Learning Processes and Organizational Competence

By Sidney Winter

It seems familiar enough that business firms and other organizations "know how to do things," things like building automobiles or computers, or flying us from one continent to another. On second thought, what does this mean? Does "organizational knowledge" exist, or can only a human mind possess knowledge? If organizational knowledge is real, what principles govern how firms acquire, maintain, extend and sometimes lose knowledge?

Organizational Knowledge

A fundamental assumption of the TED Project is that organizational knowledge does exist, founded on learning by individual human beings within a shared organizational context. This shared context is the key to why an organization's knowledge adds up to something more than the sum of its human parts, and to the ability of organizations to reproduce stable patterns of productive performance, while individual humans come and go. Organizations develop and maintain productive knowledge across a spectrum ranging from routine and repetitive patterns of activity to problem-solving activities requiring specialized analytical skills, and ultimately to shared "mental models" of the organization's place in the world at large.

All these forms of knowledge affect the organization's ability to survive and prosper in its environment—in the case of a business firm, an environment where competition from rival firms typically sets the standard for survival and growth. Knowledge plays a major role in defining the organization's opportunities and constraints. Although adaptive change in the knowledge base may point the way to new activities the firm might undertake, difficulties in phasing out old activities and in pursuing new ones arise. Established routines, analytical frameworks and mental models are hard to change or abandon. The knowledge base thus plays a quasi-genetic role in economic evolution, providing a powerful source of behavioral stability at the firm level, while the selective feedback from the marketplace works over time to sort the successes from the failures.

The TED Project's June 1994 workshop "The Nature and Dynamics of Organizational Capabilities" was designed to promote an empirically grounded discussion of conceptual and theoretical issues relating to organizational learning and the nature of organizational capabilities. Presentations by researchers studying particular industries provided the group with perspectives on capabilities in a variety of real-world contexts from pizza franchises to computers. →

Technology Transfer

Some themes emerged in the discussion that facilitate comparative analysis, and may provide guidance for construction of a general theoretical framework for evolutionary economics. For example, the transfer of an advantageous new capability from one site to another may face serious organizational challenges.

Technology transfer problems can arise in any industry. For example, imagine preparing pepperoni pizza. The straightforward approach of arranging the pepperoni on a bed of shredded cheese fails, because the pepperoni slices begin to drift as the cheese melts. An employee in one outlet of a national pizza chain developed by trial and error a technique that correctly anticipated the dynamics of melting cheese. The pepperoni still floated on molten cheese, but ended up in a pleasing pattern. The new technique spread quickly among outlets with the same owner as the innovating site, but unintentional organizational barriers barred its spread to other outlets in the national chain, despite efforts at promotion.

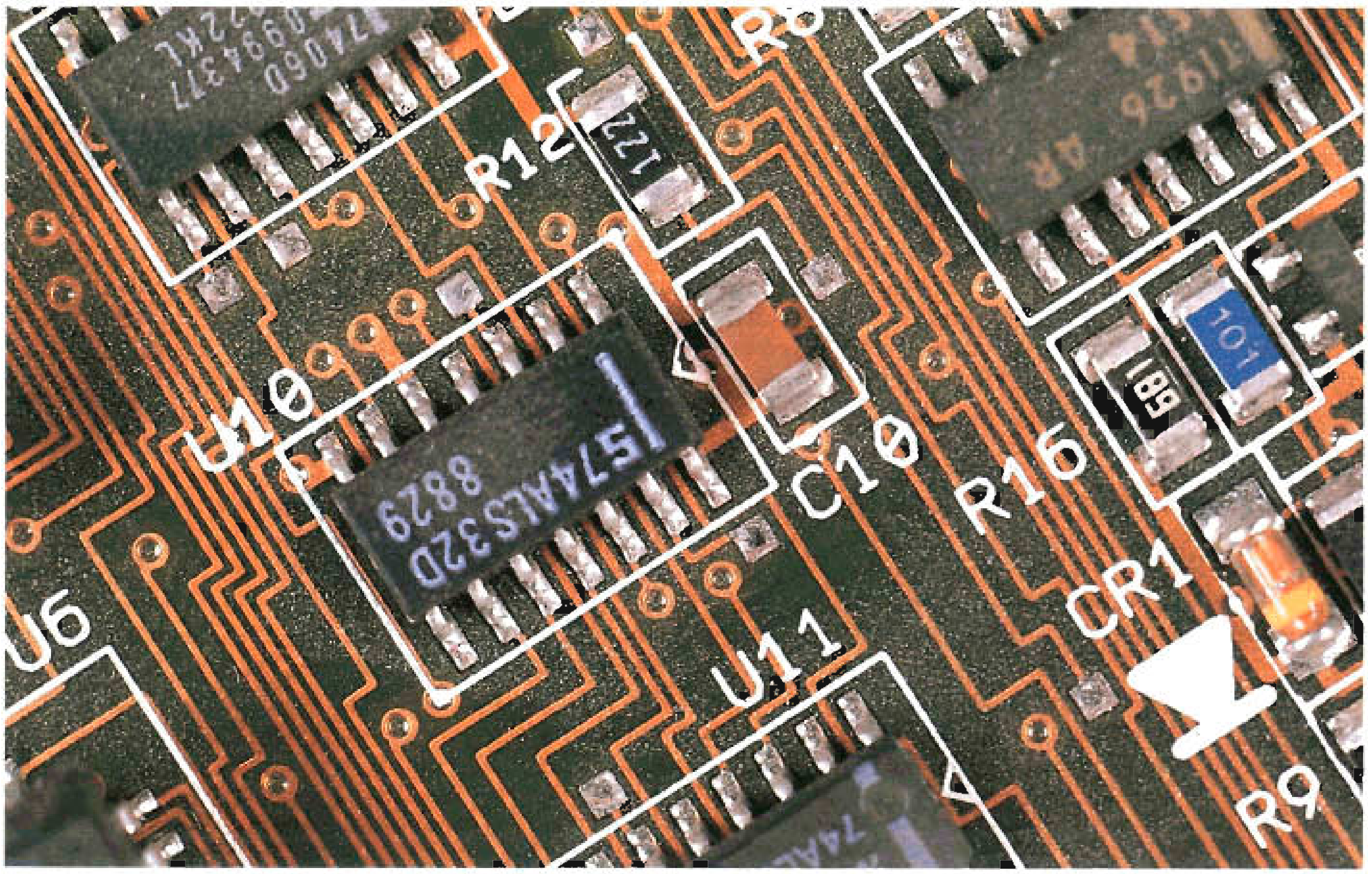
In the semiconductor industry, a crucial technology transfer step occurs as a chip design graduates from "lab to fab," that is, from the level of prototype production in the design lab to volume production in the fabrication facility. An elegant design that costs too much or designers who will not stop tinkering can block the smooth flow from step to step. Two key procedures promote success in lab to fab transfer: improved communication between engineers in the two locations and ground rules that restrict the freedom to "tweak" a design once it becomes established in the fab.

Some technologies resist precise definition, making the transfer of knowledge equally difficult to pin down. The term "lean production" refers to a multi-faceted collection of organizational innovations in automobile manufacturing that has diffused widely from its origins at Toyota—but has mutated significantly as it entered new environments. Because of the complex interactions of different aspects of the lean production system, it is difficult to identify a single key to success. If there is such a key, it may consist of the effective organizational integration of policies relating to supplier relations, inventory levels, production planning, quality management, new product development and human resource practices.

A point that emerges strongly: organization really matters

Organization Matters

A point that emerges strongly from these accounts is that organization really matters: Organizational structure and its inherent boundaries present obstacles to transfer that are likely to be insuperable unless organizations specifically and energetically act to overcome them. This observation underscores the validity of a major premise of this part of the TED Project: The study of productive capabilities cannot address only technology in a narrow sense, but must encompass the organizational arrangements through which the work gets done. ■



Technological and Industrial Dynamics

By Giovanni Dosi

Today we know much more than, say, twenty years ago, about the mechanisms, opportunities and incentives that drive technological change in industry. A rapidly growing research literature—to which several members of the TED Project have made significant contributions—is shedding new light on the process by which profit-motivated firms search for new techniques of production, new products and new organizational arrangements.

Technological Learning in a Specific Marketplace

These search efforts—often doomed to failure, but sometimes reaping impressive rewards—do not occur in an institutional vacuum. There is no such thing as an abstract "marketplace." The opportunities, incentives and constraints that firms face are embedded in a web of specific linkages with universities, technical organizations, training institutions, regulatory agencies, etc. One of the topics currently under investigation by TED researchers concerns the nature of these institutions and the ways they influence technological advance.

Moreover, at least two general features of technological learning have emerged from this and previous research. (These hold from sector to sector and from country to country, despite institutional specificities.)

1. Many learning activities involve an increasing "easiness" of advance proportional to what is already known, a process called "dynamic increasing returns." In other words, the more you learn, the easier it is to learn more.

2. In most industries, learning does not occur in a random direction, but is shaped by commonly shared bodies of knowledge, called "technological paradigms." In turn, technological paradigms, once they become established, sometimes yield a basic configuration of artifacts, or dominant designs. Think, for example, of cars or aircraft, televisions or radios. All models share solutions to certain technical problems, such as the transformation of heat into mechanical movement in engines and the broadcast and reception of electromagnetic signals in television and radio. Competition among different products revolves around precisely how well firms carry out these common solutions.

Different Sectors, Different Opportunities

Although these general characteristics of technological progress hold across sectors and national boundaries, some intersectoral and international differences stand out.

For example, the sources of innovative opportunities vary considerably from sector to sector. Some sectors draw directly from advances in scientific knowledge—for example, bioengineering. Others, such as the machine tool industry, draw from more informal experience in design and interaction with customers. And in sectors such as textiles, innovations are mainly embodied in purchased capital equipment and intermediate inputs.

Specific national institutional contexts are also likely to influence the specific forms by which firms learn new technologies. Established firms may dominate new technologies in one context, while new firms do so in another. Furthermore, government procurement or consumer demand may shape "trajectories" of progress.

The TED Project addresses the general issue of coevolution between technologies, organizational forms and industrial structures

Several major questions remain: How do technological and organizational changes influence the dynamics of industrial structures, the size distribution of firms, changes in market shares over time, the birthrates and death-rates of firms, and the distributions in revealed productivity and innovative performances?

In some sectors, "early movers" get a long-lasting cumulative advantage. For example, the major U.S. auto makers dominated for more than half a century, while IBM dominated the computer industry for about four decades. In other cases, past successes appear to hinder efforts to explore new technologies. At least in the United States, established pharmaceutical firms have yet to cash in on biotechnology, leaving the field open for start-ups.

Economic Coevolution

The TED Project addresses the general issue of coevolution between technologies, organizational forms and industrial structures. We ask how particular patterns of industrial change ("learning regimes") influence the economic environment ("industrial structures"), and how the economic environment in turn strongly influences both survival rates of firms and the direction of future change.

At the TED workshop held at IIASA in July 1994, scholars from Statistics Canada, the U.S. Department of Commerce and The Science Center in Berlin, among others, addressed two major issues. First, they attempted a thorough assessment of what we know—and what we do not know—about industrial demography and industrial change. They attempted, for example, to sort out the relative contributions of established firms and new firms to productivity growth and employment creation. Second, participants attempted to prepare the ground for a dialogue between evolutionary modelers and empirically minded researchers, groups who rarely compare →

notes. One of the unique features of the TED Project is to bring these two types of researchers together and give them the opportunity to talk to one another.

Current Projects, Future Applications

Current TED activities include work on several original empirical papers detailing economic regularities, that is, "stylized facts." At the same time, TED researchers are developing models of industrial dynamics that attempt to explain and raise new questions about these stylized facts, with the long-term goal of enabling policy-makers to draw policy implications from the models.

Such implications are likely to require fine tuning to the specific economic situation. For example, under some technological regimes, government and institutional support for research and development might be quite helpful, while under others, it might prove useless. Or, a dominant market share may represent evidence of unfair restrictive practices demanding antitrust measures in one sector or situation, while in another, large size might only represent the advantage of different technological capabilities. Antitrust actions in this situation would mainly imply killing the "hopeful monsters" nurtured by economic evolutionary forces. ■

Innovation, Competition and Macrodynamics

By Richard Nelson

The historical record of economic growth over the past two and a half centuries is rich and complex. Sustained growth of worker productivity and per capita income, associated with the development of new technologies and rising capital intensity of production, is a phenomenon that only really began in the last decades of the eighteenth century.

Discontinuous Economic Growth

Economic growth rates tended to increase from the early decades of the nineteenth century to the early decades of the twentieth. The period from the end of World War II until 1970 saw even more rapid growth rates in many countries, followed since 1970 by significant slowing. Different eras have been marked by different leading industries. As the leading technologies have changed, the nature of the economic institutions associated with their rapid development has changed as well.

Until the late 19th century, rapid sustained economic growth was almost exclusively a phenomenon of Western Europe and its overseas offspring. Great Britain was the early growth leader, but by the late 19th century, leadership in many fields had passed to the United States and in some fields to Germany. Somewhat later, Japan joined the growth club, followed after World War II by a number of other countries. Today, much of the world remains economically disadvantaged and dirt poor.

Growth Theories

Recognition of the richness and complexity of the economic growth record raises fundamental questions regarding the phenomena that economic growth theory ought to address. It is too much to ask of any theory in economics, or in the social sciences more generally, that it fully explain all aspects of the growth record. Clearly a satisfactory theory of economic growth needs to be able to explain the movement over time of broad aggregate measures, such as gross national product, and to illuminate differences in the growth experiences among countries.

But must a satisfactory growth theory recognize explicitly that different eras are marked by different leading industries? Must it contain a realistic treatment of the processes of technological advance? To what extent must a satisfactory growth theory track the development of important institutions, like the rise of large modern corporations or research universities? While sophisticated historical accounts of economic growth recognize all these variables, more formal growth theories tend to focus on just a few.

A TED Workshop

The third TED workshop—on understanding growth as an evolutionary process—took place at IIASA in late June 1995. The workshop followed the format employed in the prior two. Participants considered in detail the empirical phenomena requiring explanation, then moved on to a discussion of broad theory and particular models.

The discussions at the workshop suggested the existence of three very different kinds of economic growth theories. One focuses largely on quantitative statistical aggregates. It is centrally concerned with the relationships between input growth, (in particular, growth of capital per worker), and output growth (in particular output per worker). Technological advance appears largely as a "residual," associated in some recent theories with investments in research and development, human capital, and other quantitative variables. However, theories of this genre tend not to concern themselves with the details of the processes through which technological advance occurs, bringing institutions into the discussion only as qualitative background variables.

While there are fewer representative examples, another genre of growth theory tends to focus on national institutions, seeing these as providing the structure within which technological advance, input growth and output growth proceed. These theories, including the Régulation approach, developed particularly in France, focus on the national economy as a complex economic, political, social and cultural system that molds relationships among the actors, their expectations and behavior towards one another. →

→ Evolutionary theories of economic growth, the third genre, tend to have several central defining properties. First, they focus centrally on the processes involved in technological advance. Second, they focus at least as much on the forces tending to upset equilibrium as they do on the forces tending to move the economy towards equilibrium. Third, evolutionary theorists tend to cast individual business firms in a central role in economic change. Within evolutionary theories, growth of output and capital at a macroeconomic level are treated as the consequences of the microeconomic processes generating and spreading technological advance. As in the first genre of theories, formal evolutionary models tend to treat institutions as important qualitative variables.

Future Directions

The workshop focused more on evolutionary theory of economic growth than on the other two broad kinds of theories (but also began investigating possible bridges with the second, institution-centered approach). The central purpose was to identify future directions for further evolutionary theorizing. The following points emerged from discussions.

First, there is a very large gap between verbal statements and formal modeling regarding the central role of economic institutions in evolutionary theory. Economists have made some progress over the last decade in modeling institutions, often using the language and concepts of game theory, and this clearly is one route that evolutionary growth theorists ought to consider. However, the modeling of institutions in evolutionary growth theory remains a challenge.

Second, growth theories in general, and to some extent also many current models in evolutionary growth theory, tend to agree better with data concerning relatively smooth continuing growth than with data concerning turning points or sharp changes in the pace and pattern of economic growth. In this respect, evolutionary growth theory may have a built-in advantage over the other two kinds of growth theory, in that it naturally adapts to techniques of nonlinear dynamic modeling. However, a huge gap remains between demonstrating that a stylized formal evolutionary growth model has the capability of generating cycles in growth and divergent behaviors of national economies, and showing that this theory provides an intellectually satisfying and deep explanation for particular changes. These two broad directions—formal modeling of institutions and a better grip on how patterns of economic growth change—top the agenda for future evolutionary theorizing about economic growth. ■

Modern Perspectives on Economic Growth

A Joint Symposium of
the Canadian Institute for Advanced Research (CIAR) and IIASA,
Ottawa, Canada, 26-27 March 1995

Canadian Minister of Industry John Manley addressed a dinner hosted by CIAR on 27 March at the Chateau Laurier Hotel in Ottawa. At left: CIAR President J. Fraser Mustard and IIASA Director Peter E. de Jánosi

Some of the world's leading experts in the fields of evolutionary economics and the new economic growth theory met in Ottawa this spring. The Symposium, initiated by the Canadian Committee for IIASA and CIAR, and sponsored by Industry Canada and the Canadian Imperial Bank of Commerce, brought together the economic work of the two research organizations. Some 30 international experts discussed research on economic growth and innovation, and provided a forward outlook for public policy discussions that is different from traditional approaches. The meeting focused on the role of innovation, technological change, and industrial dynamics and gave particular attention to the value of human capital, knowledge and organizational competence.

In an open session attended by some 150 participants, Richard Nelson of Columbia University and IIASA, and Paul Romer, Royal Bank Fellow in the CIAR Program in Economic Growth and Policy, provided a historical and theoretical perspective on the puzzle and progress in understanding the determinants of economic growth. ■

Methodology and Modeling

By Yuri Kaniovski

Explaining the process of economic change poses one of the most important challenges to any economic theory. One inroad into understanding change is by means of evolutionary models, in which business firms are the central agents. Firms whose research and development turns up more profitable production processes or products will grow in the market environment faster than their competitors. The competitors, for their part, may at some point attempt to imitate profitable innovations. Firms change continuously, partly by searching for more effective technologies, investment rules, or even improvements of their search procedures. All of these aspects have been referred to as routines. Inefficient firms may fail, while a flow of new firms into the industry continuously introduces more variation into the set of competing technologies and behavioral rules. As a result, the population of firms remains heterogeneous. The future evolution of the industry can only build on existing characteristics, which constrain the outcomes that may (or may not) occur. This mechanism, however, also incorporates a degree of chance. The logic of such models typify what mathematicians call a "stochastic dynamic system," which can be modeled as a Markov process in discrete time and in a high-dimensional space.

A Standard Cycle

A standard cycle can be described as follows: At one moment in time, a firm can be characterized by its capital stock and prevailing routines. These routines determine the inputs and outputs of the firms. The market determines firms' profitabilities and changes in market shares, given the technologies and other routines in use. Profits, together with the investment rules of the firms, determine whether they expand or contract. Search routines implemented by firms attempt to improve some aspects of firm behavior, capabilities and technologies, and may come up with proposed modifications, which may or may not be adopted. The system is now ready for the next iteration.

Firms in the model behave similarly to the way humans appear to in models of most other social science disciplines, except neoclassical economics. They are influenced by habits, customs or beliefs. Evolutionary economic theory makes no presumption, as neoclassical theory does, that what firms do is optimal, except that, metaphorically speaking, they attempt to do the best they can. At the same time, firms can discover new behavioral rules or new technologies, and thus they can internally expand the range of operational opportunities available to them.

Modeling Evolution

The TED Project has proceeded along two complementary modeling paths. The first includes more phenomenological and behavioral details and relies mainly on simulation techniques. This type of model attempts to show that, with economically meaningful system parameters and behavioral rules, macroeconomic regularities emerge from underlying microeconomic interactions.

The second style of modeling focuses on more stylized and parsimonious representations of the dynamics of technologies, expectations, organizational customs, and behaviors. These changes tend to reinforce themselves, →

The Systems Analysis of Technological and Economic Dynamics Project

In its second year, the **TED Project** comprises an international, interdisciplinary network of researchers under the leadership of **Giovanni Dosi**, Department of Economics, University of Rome "La Sapienza," in close collaboration with **Richard Nelson**, Columbia University, New York and **Sidney G. Winter**, Wharton School, University of Pennsylvania. IIASA is the base for a small resident team of researchers, including **Yuri Kaniovski**, V.M. Glushkov Institute of Cybernetics, Kiev; **Gerald Silverberg**, MERIT, University of Limburg; **Francesca Chiaromonte**, School of Statistics, University of Minnesota; **Marco Valente**, University of Manchester; and **Walter Fontana**, University of Vienna. Other members of the collaborating research network are not full time at IIASA.

The following researchers also play major roles:
- **Serguei Glaziev** and **Valery L. Makarov**, CEMI, Moscow
- **Franco Malerba** and **Luigi Orsenigo**, University Luigi Bocconi, Milan
- **Massimo Egioli** and **Luigi Marengo**, University of Trento
- **Luc Soete** and **Bart Verspagen**, MERIT, University of Limburg

A collaborating French team includes, among other researchers, Robert Boyer, Pascal Petit, Bruno Amable and Eve Caroli, CEPREMAP, Paris; André Orlean, CREA/Ecole Politechnique, Paris; Jacques Lesourne, CNAM, Paris; Benjamin Coriat and Helene Tordjman, CREI, University of Paris XIII.

Other TED collaborators are at Stanford University; University of California Berkeley; Johns Hopkins University; the Science Policy Research Unit (SPRU), University of Sussex; Statistics Canada; the Santa Fe Institute; the Technical Research Center of Finland and VTT Automation, Espoo; the Research Institute of the Finnish Economy, Helsinki; the Technical Universities of Wroclaw and Berlin.

forming a feedback loop that maintains behaviors despite their actual effects on performances. Therefore, small historical events may exert a cumulative impact on future developments, locking in particular configurations of technologies or behaviors, even when they are far from optimal.

Some aspects of these basic models can be studied analytically, leading to exciting mathematical challenges concerning the analytical properties of stochastic dynamic systems. In this respect, classical mathematical results, appropriately modified, are becoming convenient and powerful tools in the study of evolutionary economic processes.

Capturing Competition

These models typically produce many possible outcomes, each a result of a dynamic learning process. To capture the underlying competitive process, a wide variety of mathematical approaches has been suggested from within and outside economic analysis, including ordinary differential and difference equations and stochastic differential equations (in particular those with trajectories on the unit simplex—replicator equations—or in the stochastic case, urn processes). TED Project members are developing and applying several of these methods of analysis, for example, "Generalized Urn Schemes."

To illustrate an urn scheme as applied to evolutionary economics, imagine a large (in the ideal case, infinite) pool of adopters of two competing technologies, say A and B. When the process starts, some adopters use A and some B. Because potential adopters are less than perfectly informed about the two technologies, they use probabilistic rules for deciding which technology to adopt. For example, they might use a majority rule: Take a sample of those already using the technologies and choose the one the majority uses. The sample size reflects the extent to which adopters get along with and imitate their friends and neighbors in the economic neighborhood (see Figure).

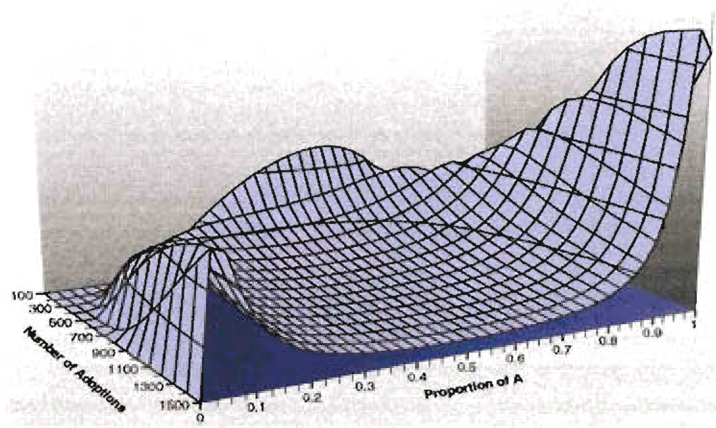
As more agents adopt one of the two technologies, the relative shares of the technologies may reach a relatively stable final state. If the process of adoption begins with more agents using technology A, A is more likely to end up being more widely used. In some cases, A will dominate even if it competes with an "objectively better" technology. In any case, randomness affects the final state to which the system converges.

This simple, basic scheme can be applied, with appropriate modifications, to so-called "evolutionary games with incomplete information." Consider two groups of economic agents repeatedly playing a game in which the agents have only incomplete information about the payoffs (the outcomes of their actions). The fact that agents do not know with certainty how successful their previous strategies have been introduces a random element into the process. Nonetheless, agents adapt as the game continues and may discover consistent solutions after sufficient time has elapsed.

Urn schemes allow the analysis of adaptive learning processes, in which, for example, one group of agents tries to infer "what is best to do" from the second group and vice versa. Each agent changes its strategy continuously during the process. Will the dynamics converge to some stable "conventional" behavioral pattern? Or will the system continue to fluctuate over time? And if it does converge, what are the properties of the "conventional" behavioral pattern? A current collaboration between TED and Dynamic Systems Project members addresses these issues.

Current and Future Connections

TED's contributions to the analysis of economic evolution link with parallel developments in other fields of research, such as the evolution of complex structures in biology and theories of adaptive learning and emergent computation. At the same time, the TED Project is currently developing a library of computer program modules for the simulation of evolutionary models. These modules will allow researchers to use learning processes and market interaction mechanisms with conditions drawn from existing models and also to experiment more easily with new ones. Within about two years, TED researchers hope to create unified software addressing a range of models. This should allow scientists inside and outside of the TED network to run their own simulations, possibly discovering new patterns of complex economic behavior. ■



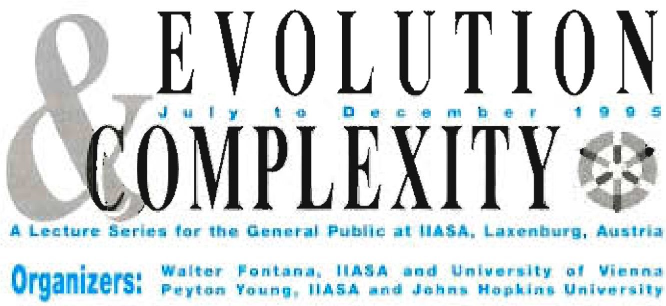
The figure shows the probability distribution of the proportion of economic agents using technology A as new adoptions are made over time. Technology A starts out with a very slight preponderance (the initial numbers are 18 for A and 17 for B, with a sample size of 5). From a unimodal distribution, the system bifurcates into a bimodal one, with the highest probability for A almost completely dominating, a substantial probability for B dominating, and very low probabilities for coexistence. In the limit, the distribution becomes a binary one concentrated at the two extreme points.

1995 Tjalling Koopmans Distinguished Lecture Series

The biological, physical and social sciences are currently undergoing a significant change as they adjust their goals and techniques to understand complex, evolving systems. Species and ecologies, firms and markets, brains and computers, societies and cultures are but a few examples of such systems, which have the ability to reconfigure themselves and to generate new parts in response to internal or external events. This invites a generalization of the concept of evolution from biology to a far broader domain of complex structures. These forms of organization are characterized by many interacting parts, which are capable of evolving into ever-higher levels of organization.

In this series of lectures, seven distinguished scholars speak about their scientific research and how it reflects these new challenges. They will raise provocative questions that as yet have no definite answers; this serves as a reminder that evolution and complexity are the product of growth and interaction.

With this series, IIASA continues its commitment to cross traditional boundaries and to foster innovative thinking.



In the first Tjalling Koopmans Distinguished Lecture, **Professor Peter Schuster** spoke about "Molecular Evolutionary Biology—From Concepts to Technology," how chemists are using Darwinian evolution to build new molecules in the laboratory.

Schuster, of the University of Vienna and the Institute for Molecular Biotechnology, Jena, said chemists mimic the three main steps of biological evolution in evolving novel chemicals—primarily nucleic acids such as RNA and DNA. First, they use modern biochemical methods to multiply even a single copy of a nucleic acid into millions of slightly different copies. Next, they select among the resulting molecules according to some criterion. This step, Schuster said, employs chemical creativity. If the chemist wants an RNA that binds to another molecule, for example, he can fix that molecule to a surface and flow a solution of candidate RNAs over the surface. Those that do not bind wash away. After removing the bound RNAs with a different solvent, the chemist uses them as starting material for another round of evolution. Within a few generations, new RNAs with high binding capacity have evolved.

By using these techniques, Schuster said, chemists may develop a wide variety of new drugs, analytics, biosensors, diagnostics and even chemicals useful in environmental remediation.

In the second lecture of the series, **Professor Atlee Jackson** forecast "The Second Metamorphosis of Science." Jackson, Director of the Center for Complex Systems Research, University of Illinois at Urbana-Champaign, said the first metamorphosis occurred between the late 1500s and late 1700s, with the work of Newton, Kepler and others, which unified the terrestrial and celestial realms and brought to light universal physical laws.

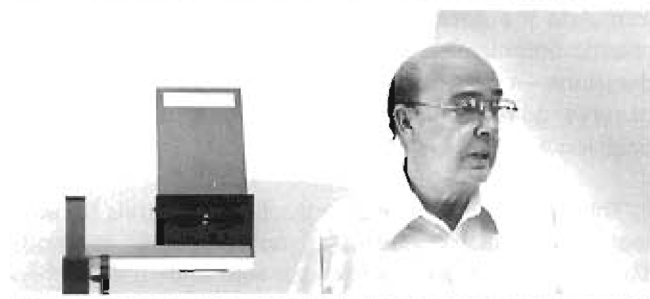
But the mathematical discoveries of Poincaré in the late 1800s introduced the possibility of chaotic behavior in "simple" Newtonian systems. The introduction and proliferation of the digital computer in the past four decades has brought to light more chaotic and dynamic behaviors of physical systems, and allowed physicists to study such behavior as well as new phenomena, such as fractal geometry.

These two advances, Jackson maintained, make it clear that the holy grail of some physicists—a theory of everything—will not be achieved. Instead, Jackson urges physicists to take chaos and other dynamic behaviors into account with a view toward modernizing the basics of scientific method.

Other Lectures in the series include:

- **Bernardo Huberman**, Xerox Palo Alto Research Center, "Better Than the Best—the Value of Cooperation," 4 September
- **Lynn Margulis**, University of Massachusetts, "What is Life," 13 September
- **John Padgett**, University of Chicago, "Social Networks and Markets," 13 October
- **Günter P. Wagner**, Yale University, "The Evolution of Complexity," 10 November
- **Bruno Buchberger**, Research Institute for Symbolic Computation in Linz, "Symbolic Computation: Organizing Complex Reasoning," 1 December

All lectures start at 11:00 a.m. For further information, call +43 2236 807-256 or e-mail kasriel@iiasa.ac.at ■



Prof. Atlee Jackson at the second Koopmans Lecture on 21 July 1995

Modeling Uncertainty

By Andrzej Ruszczyński

The question "What is the cleanest energy technology?" will always be answered in a certain way, for example: "Support solar power." Building a mathematical model to determine the answer, a "deterministic model," still yields only this type of answer, though the particular energy source named may change as the complexity of the model increases. But without knowing the future, investing all research resources in a single technology may represent too much risk, no matter how sophisticated the model. The fact that we don't know some aspects of the future comes as no surprise. But incorporating that uncertainty into mathematical models proves surprisingly challenging.

An example of a stochastic optimization problem

$$\min Ef(x,\omega)$$
$$P\{g(x,\omega)\le b\}\ge 1-\delta$$
$$x\in X$$

Large-scale problems, such as how to manage a nation's economy, energy policy, population or environment, share several general features—complexity, dynamics and uncertainty—that make systems analysis particularly difficult. Standard analytical methods go a long way toward adequately modeling complexity and dynamics, but incorporating uncertainty presents additional difficulties. Missing or inaccurate current data, errors in forecasting future data, external uncontrollable disturbances, such as weather or actions of independent agents—all introduce uncertainty.

Many systems analysts use large scale models to try to predict how changes in different aspects of human society will affect and be affected by the natural world. One class of such models deals specifically with the relationship between human economic activity and environmental quality. These models attempt to describe the complicated interplay among resource availability, environmental quality, and consumer preference. Governments may use such models to help reach national economic decisions—decisions such as whether, when and how to tax or subsidize. Ignoring uncertainty and its potential costs can prove perilous. To make such decision models effective, analysts must therefore actively take account of uncertainty. One promising way is to model uncertain quantities by random variables and to formulate the decision model mathematically as a "stochastic optimization problem." From among all possible decisions—say, which supposedly "clean" technologies deserve government support—analysts search for the decision with the lowest expected cost.

This technique allows construction of models linked to real data using rigorous mathematical methods. Techniques for their solution can also have a solid theoretical background. Thus such models can produce qualitatively and quantitatively meaningful results about problems confronting decision makers.

The analysis of stochastic optimization models suggests decision types that differ qualitatively from the solutions of deterministic problems. The concept of flexibility, the ability to respond to the uncertain future, and the idea of diversification as insurance against uncertainty all emerge from stochastic optimization models. We ask, for example, "Which is the best mix of energy technologies to protect the environment and ensure sufficient energy?" rather than "Which is the cleanest technology?"

Finite Scenario Approximations

One theoretically sound step toward answering such questions is to approximate uncertainty in a problem by constructing a finite number of scenarios. Here, a scenario means a certain set of data that can be used in the model to fully determine its output. Finding a solution that is good for many such data sets can produce an approximate solution to the overall problem with uncertainty.

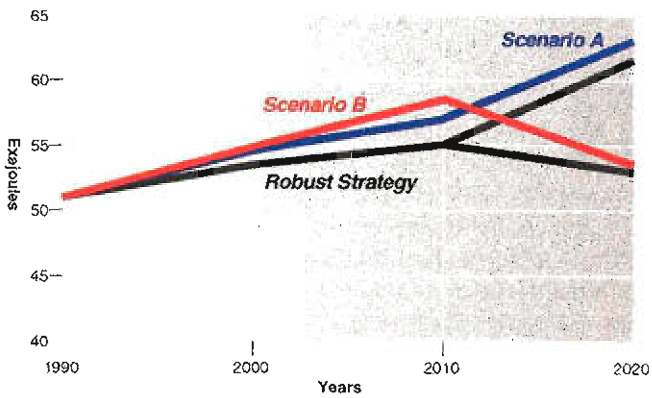
Fundamental questions remain regarding the relationship between these approximations and reality, however. In particular, as the number of scenarios grows, does the approximation approach the real problem? Should analysts select sample scenarios at random, or find certain critical scenarios? Such questions have direct implications for numerical methods and for particular application problems, and therefore Optimization Project members address them theoretically.

Scenario Decomposition Methods

Using finite scenario approximations, analysts can present decision makers with several possible solutions, each produced by a single scenario. But an implementable strategy may not emerge from such a multiplicity of solutions. One approach to narrowing the field of possibilities is to modify the model until several scenarios yield the same solution: the best decision in the presence of uncertainty. This approach, called coordinating solutions, often takes the form of adding costs and benefits to a model to account for the hidden effects of uncertainty.

Such an approach is well suited to applications for many reasons. First, scenario-based models may be broken into subproblems, copies of a deterministic model that is usually well-understood. This facilitates the use of knowledge and computer programs accumulated in an →

→ earlier stage of the research. Second, scenario decomposition methods provide an important insight into the problem by explicitly dealing with the necessity of making decisions before uncertain data is known. This analysis provides us with estimates of the acceptable costs of reducing uncertainty. Furthermore, scenario decomposition methods, although slower for small problems, can solve large problems with many scenarios. Apart from computational advantages, they also provide an insight into the structure of the problem by providing the price of uncertainty. One recent achievement of the Project is the development of two original coordination mechanisms for scenario decomposition methods.



Scenarios A and B describe two possibilities for the future. Scenario A (red) suggests heavy use of nonelectric power. Scenario B (blue) suggests modest use. The scenarios are constructed so as to simulate a major change occurring in the year 2010, when nonelectric energy will be found either as productive as it currently is, or much less productive. If the future could be predicted, scenario A would best prepare for a future in which nonelectric energy continues to be productive. Scenario B would best prepare for a future in which nonelectric energy proves less productive. A stochastic optimization program designed to deal with uncertainty about the future ("robust" strategy, green) surprisingly plots a course with even more modest use of nonelectric energy. This robust strategy, it turns out, allows the most flexibility (green line splits) once the value of nonelectric energy becomes known.

Uncertainty: better to model it than ignore it

Application to Energy Modeling

The techniques developed in this Project have been applied to a number of environmental problems studied by other IIASA projects. For example, the impact of uncertainty on optimal strategies for reducing sulfur emissions was analyzed. Another application that may have a substantial impact on further research was a modeling exercise performed with the help of IIASA's Environmentally Compatible Energy Strategies Project. A stochastic, eight-scenario version of Global 2100—a large scale, deterministic, macroeconomic model—was developed. The eight scenarios modeled, in addition to other things, the perceived uncertainty in the importance of nonelectric energy usage to overall economic output over time (see Figure).This was the first attempt to incorporate uncertainty into a macroeconomic model used by energy modelers, and it inspired other researchers to follow this lead.

New Research Directions

Clearly, the theoretical approaches and the applications mentioned above do not fully exploit the wealth of possible questions associated with optimization under uncertainty. Optimization problems appear over and over again in different applications, and uncertainty is one of the key difficulties in long-term planning models. There will always be a need for approaches that address these issues on solid mathematical ground and lead to practical modeling methods. ■

Optimization Under Uncertainty Project

Motivated by an inspiring array of applications to macroeconomic and environmental problems supplied in part by the rich mix of other IIASA projects, Optimization Under Uncertainty Project members attempt to develop practical modeling techniques for incorporating uncertainty into long-term investment planning problems in environmental protection.

In particular, the Project develops modeling techniques that build on existing deterministic models, as well as flexible and practical techniques for solving such realistic models that include uncertainty. Only a narrow class of such problems yield to analytical methods. Real-world problems usually require computational approaches. However, existing computational methods of optimization cannot solve problems with uncertainty. The main difficulty is the enormous size of such problems, orders of magnitude above the capabilities of existing methods. What are needed are special methods that split problems with uncertainty into smaller, manageable pieces.

Project members also develop specialized versions of the general modeling and solution techniques for some of the applied models analyzed at IIASA. Such detailed case studies should help to identify strengths and weaknesses of the methods and to motivate future research.

Project Members:

Project Leader **Andrzej Ruszczyński** (Poland), Warsaw University of Technology
Vladimir I. Norkin (Ukraine) , V. M. Glushkov Institute of Cybernetics, Kiev
Georg Ch. Pflug (Austria), University of Vienna
Charles H. Rosa (USA), Decision and Information Sciences Division, Argonne National Laboratory, Argonne, Illinois

Evolution of Cooperation

In the decades after Charles Darwin revolutionized biology with his *The Origin of Species*, published in 1859, the public perception of natural selection has featured a process producing a dog-eat-dog world in which only the fittest survive. And "fittest" has often been interpreted as the toughest, the most aggressive and the most ruthless.

But numerous examples seem to fly in the face of this grim scenario, not the least of which is human society. From the first hunting parties to modern societies, we generally work together for our mutual benefit. Now we donate part of our incomes to support those without jobs, and to educate those too young to work. We work in teams and cooperate with our relatives in families. We paint the natural world, however, as more savage than human society. But humans are not the only organisms to cooperate. From cooperating relatives to members of different species locked into interdependence, other organisms work together for their mutual benefit. The latter case, in which members of two species share a close, mutually beneficial relationship, is called "mutualism." Other similar relationships, such as parasitism, appear more lopsided, benefiting one species more than another. As scientists gather examples of cooperation at many levels, they increasingly recognize the importance of cooperation in the evolution of life.

Kin Selection

One of the earliest recognized examples of natural cooperation is that of the social insects. Many bees, wasps and termites live in huge colonies that hum along with seemingly perfect harmony. Seen up close, a honeybee hive shows an even greater degree of cooperation. The workers, who flit from hive to flower gathering nectar, are all females, and none of them reproduces. Instead, they devote their lives to the good of the hive and cooperatively care for the offspring of the queen.

Natural selection acts only on the individual, helping or hindering her in passing genes on to future generations. How then can it serve a worker bee's genetic interests to rear the queen's children, but none of her own? Geneticists in the 1960s suggested an answer that helps explain not only the evolution of social insects, but of family cooperation among all living things. Because only the queen reproduces, all workers in a hive are sisters and share most of their genes. As long as her sisters grow and survive, and the queen continues to lay eggs, many of a worker's genes do survive. If the queen dies, or the colony grows overlarge and splits, one of the worker's sisters will become the new queen (by receiving special food) and the worker still wins from a genetic point of view.

In less extreme instances, many animals help rear, protect or feed their kin. Female Belding's ground squirrels, female African elephants and female dolphins live in multigeneration cooperative groups of closely related individuals, cooperatively rearing young. Sometimes a cooperative strategy just makes common sense. Redwing blackbird females mate with more than one male during a season, so a male protecting a nest may be aiding his rivals. But because most of the chicks in his nest are his, he cares for them all, avoiding the risk of letting one of his own offspring starve.

This basis for cooperation, or altruistic behavior, scientists call "kin selection", adding a twist to the concept of natural selection. An individual can succeed in the genetic game by passing on his or her genes directly to descendants or by supporting kin who share those genes.

The Evolution and Ecology of Mutualism: An IIASA Workshop

Laxenburg, May 12-15, 1995

IIASA researchers **Karl Sigmund** and **Peyton Young**, along with **Eörs Szathmáry** of Eötvös University in Budapest, Hungary, organized an IIASA workshop called "The Evolution and Ecology of Mutualism," May 12-15, 1995.

The workshop brought together scientists from Canada, Europe and the United States. Participants shared their expertise and insights into the effects of cooperation—from the level of molecules to communities of animals—to further their mutual understanding of mutualism.

Topics included:

- Models of molecular mutualism: different means of cooperation
- Population structure and the maintenance of mutualism
- From parasite to mutualist: the role of transmission
- Macroevolutionary role of endosymbioses
- Community evolution and positive effects

Games and Shared Gains

A different explanation of biological cooperation, one that applies more widely to human society and to many examples in the natural world, relies on shared gain. This hypothesis, called "reciprocal altruism," supposes that by cooperating, an individual will gain cooperation from others during many later interactions. But how can an individual "decide" when to cooperate?

Evolutionary scientists have relied on game theory to plumb the logic behind individual actions under natural selection. The Prisoners' Dilemma game typifies this research strategy. The game involves two players who each choose to cooperate or refuse to cooperate, called defecting. If both players cooperate, each wins three →

points. If both defect, each wins one point. But if one decides to cooperate, the other may defect. In this situation, the defector wins and takes five points; the cooperator gains nothing. Cooperation therefore confers a great risk. Each player's best strategy at each turn is to refuse cooperation. Thus the Prisoner's Dilemma seems to support the cynical view of life.

The longer-term view, however, provides some surprises. In a tournament of computer programs plying various strategies in repeated rounds of the Prisoner's Dilemma, a strategy called "Tit for Tat" won hands down. It merely repeated the opponent's last move, never gaining a lead in any individual contest, but finishing the tournament with the most points. Later, by allowing the programs to "evolve," scientists found that Tit for Tat engendered the evolution of a more cooperative "population" of programs, each gaining more points by cooperating more often.

Cheaters

Cooperation is all very well when everyone cooperates, but wouldn't cheaters proliferate, bringing the whole house of cards down—at least in the real world? Observations of cooperating biological systems show this stance to be a bit alarmist. Examples of cheaters abound among animals, but the cooperative system proves plenty resilient to withstand a certain amount of cheating. The cheater's role seems like just one more ecological niche. Given the opportunity, some individuals will exploit the niche. If too many try to crowd in, they face diminishing returns.

The toadfish, a Pacific coast species, provides an interesting example of cheating within a population that breeds cooperatively. Male toadfish build large nests of pebbles and hum a love song that attracts a series of females. Each female lays eggs in the male's nest, and he fertilizes them by releasing sperm into the water. He can protect his co-op cache of eggs, and his choice nesting site, because of his larger-than-average size.

This system, however, leaves many males out. A few exploit a slim chance to pass their genes on to another generation by cheating. These smaller toadfish males employ a strategy called satellite breeding. Instead of using energy to build and protect a nest, they sneak up to another male's nest—perhaps while he's busy defending another flank—release sperm into the water, then fan the milt toward the cache of eggs with their forefins. The strategy doesn't fertilize many eggs, but suffices to maintain small males in the toadfish population.

Humans view with alarm the increase of cheating—criminal activity. But on the whole, most people follow the written and unwritten social rules, that is, they cooperate. Most drivers stop at stop signs, despite the fact that they'd gain a few minutes by speeding through. When too many people crowd the cheating niche, people who want to cooperate move out, pass more stringent laws, or more assertively apply laws on the books.

Mutualism: Older than Life

Mutualism in the strict biological sense represents far more than a curiosity of nature. Indeed, it may well be a fundamental aspect of life. For example, lichens—some of which look like light green dried leaves—consist of a mutualistic relationship between organisms from two kingdoms. A single lichen comprises a colony of single-celled green algae living in a matrix of a fungus. The fungus gains food, produced by the algae by way of photosynthesis, and the algae gain protection and moisture absorbed from the air by the fungus. Neither species can live without the other.

Our very cells provide the penultimate example of mutualism. Most biologists today agree that some components of our cells descended from primitive, bacterialike cells engulfed eons ago by larger cells. For example, the powerplants of human cells—discreet, oval organelles called mitochondria—resemble bacteria in several ways. They are the size of bacteria, have similar genetic material, and have similar chemical machinery for producing proteins. They even reproduce independently of the cell they reside in. Each of our cells "inherited" an allotment of mitochondria when its parent cell split in two.

Finally, the chain of mutualistic behavior stretches even further back in the evolution of life on earth, back to the sorts of molecules from which life arose. In mixtures, these prebiotic molecules cooperate in a sense, establishing stable reaction cycles and in some cases replicating themselves only in the company of a particular group of players. ■

IIASA at AAAS '95

IIASA's role in various major international meetings of scientists has increased significantly. Just this spring, IIASA presented a full session of lectures and a press conference at the annual meeting of the American Association for the Advancement of Science (AAAS). The AAAS meeting, under the theme "Unity in Diversity", drew thousands of scientists, business and political decision makers, media correspondents, students, and others from around the world to hear and see the latest developments in science and technology. The meeting, held in Atlanta, Georgia, USA, featured 150 scientific sessions.

The IIASA session, entitled "An Industrial Ecology View of the Society-Environment System", under the general theme of "Industry in a Global Economy", highlighted ongoing research and results from the Institute's Regional Material Balance Approaches to Long-term Environmental Policy Planning Project. William Stigliani, Scientific Project Leader, has formed an international team that uses a systems approach to analyze the causes and effects of soil contamination by tracking and accounting for flows and transformations — in production and consumption — of chemicals that eventually end up polluting the ground. Stigliani invited Project collaborators and distinguished colleagues to present their findings relevant to this topical field (see box).

The IIASA session shed light on how a systems approach can help formulate policies that effectively mitigate environmental and health-related effects posed by pollutants. Although regulations and controls in most advanced industrialized societies have resulted in cleaner air and water over the last two decades, mitigation and reduction of soil contamination lag far behind. Soil quality is worse than ever before and continues to deteriorate. The lion's share of environmental degradation has shifted from industrial production processes to consumer-related diffuse pollution, in particular the use and disposal of chemical and consumer goods, which are far more difficult to control with public policy. Polluting products, from fertilizers to nickel-cadmium batteries, are everywhere.

IIASA Press Conference in Atlanta
from left: W. Stigliani, V. Thomas, B. Wilson Shimada

"An Industrial Ecology View of the Society-Environment System"
IIASA Session at the AAAS '95 Annual Meeting
February 16-21, 1995

Presentations:

"Industrial Ecology and Dioxin"
Valerie Thomas and **Thomas G. Spiro**, Center for Energy and Environmental Studies, Princeton University, USA

"Industrial Ecology and the Nitrogen Cycle"
James M. Galloway, Environmental Sciences Department, University of Virginia, USA and IIASA, Austria

"Accumulation of Heavy Metals in Soils of the Black Triangle"
Beverly Wilson Shimada and **Peter R. Jaffe**, Department of Civil Engineering and Operations Research, Princeton University, USA and IIASA, Austria

"From Emission to Deposition on Land: Toward Sustainable Management"
William M. Stigliani, Regional Material Balance Approaches to Long-term Environmental Policy Planning Project, IIASA, Austria and Center for Energy and Environmental Education, University of Northern Iowa, USA

"Environmental Assessments of Industrial Products and Processes"
Thomas E. Graedel, AT&T Bell Laboratories, USA

The IIASA work is particularly valuable, as it is based on living laboratories — the Rhine River Basin in Germany and the Black Triangle (the Upper Elbe/Oder River Basin shared by the Czech Republic, Germany, and Poland). The Project intends to provide governments in the region with sufficient information to develop sustainable industrial and agricultural policies. General concepts based on these findings could be particularly useful in areas of the world undergoing rapid industrial development.

At the Scientific Session

Valerie Thomas of Princeton University told the audience that current human exposure to dioxins and chlorinated dioxins is much greater than in pre-industrial times. Dioxins occur in herbicides, chlorine bleach, polyvinyl chloride (PVC) plastic and other products. Health risks associated with dioxin pollution, including cancer, affect decisions about siting and operation of municipal, hazardous and hospital waste incinerators—the largest sources of these pollutants, at least in the United States. →

James Galloway, from the University of Virginia and collaborator of the IIASA Project, spoke about causes and effects of the increasing release of reactive nitrogen into our environment. He argues that by using the concepts of industrial ecology, we can transpose the environmental threat from rising levels of reactive nitrogen into positive effects by channeling the nitrogen to environments that would benefit from its presence.

Beverly Wilson Shimada, of Princeton University and a collaborator of the IIASA Project, presented findings from the Project's case study in Central Europe's Black Triangle. In this region, soil contamination by heavy metals, resulting in severe environmental damage and health risks, is extremely high. Changes in this land-use pattern, especially in light of current difficult economic conditions, have raised concern that these toxins may increasingly enter ground water and food products.

William Stigliani focused on long-term land management and the neglect of soil-related policies. Effective measures must be based on an understanding of the pathways of materials as these pass from nature, through the economy and society, and back to the environment. Stigliani called for the development of new integrated policies based on information from various disciplines including, for example, the health, atmospheric, and soil sciences.

Thomas Graedel of AT&T Bell Laboratories rounded out the AAAS '95 IIASA session, discussing the environmental responsibility of corporations. He indicated a trend toward a longer-term approach to pollution prevention, as enterprises shift from only optimizing current production to designing new products and new processes to meet future consumer demand for environmentally responsible products.

IIASA Exhibit

In response to popular demand, and as an effort to display cutting-edge science and technology, a Science Innovation Exposition ran concurrent to the AAAS annual meeting. IIASA joined an illustrious group of institutions, ranging from NASA to the U.S. Environmental Protection Agency, to inform the scientific and academic communities, the international media, and the public about recent developments and findings. ■

IIASA Exhibit at the Science Innovation Exposition

United Nations Confers Consultative Status

The United Nations has granted IIASA its high-est consultative status, category 1. The action, taken at the UN Economic and Social Council's 1995 substantive session, confers on IIASA a number of privileges and responsibilities.

Granting consultative status means the UN Council was convinced that IIASA can make significant, sustained contributions to the achievement of UN objectives, that the Institute is closely involved with the economic and social lives of people in the areas it represents, and that IIASA broadly represents major segments of the populations of many countries.

Among other privileges, IIASA may now designate official representatives to UN headquarters in New York, USA, and to UN offices in Geneva, Switzerland, and Vienna, Austria.

Furthermore, IIASA:

- will receive provisional agendas and may propose agenda items for appropriate committee meetings;
- may designate authorized observers at UN public meetings;
- may submit and have circulated to all member countries relevant written statements;
- will have access to UN libraries and press documentation services of the UN;
- may use UN accommodations for conferences and meetings relevant to the work of the Economic and Social Council;
- may be retained by the committee to undertake investigations or prepare papers;
- agrees to support the work of the UN and to promote knowledge of its principles and activities and to report on such support every fourth year. ■

Meetings

High-Level Group on Development Strategy and Management of the Market Economy
20–22 April, Laxenburg, Austria
Held at IIASA, the UN Secretariat and the UN University's WIDER organized this seminar, the second in a series cochaired by Professor Amartya Sen (Harvard University) and Professor Edmund Malinvaud (College de France). The resulting publication for policy makers will deal with practical principles for an appropriate blend of government and market action in pursuing national development objectives.
Contact: *Peter E. de Jánosi*

UNU Workshop on the Sustainable Future of the Global System
27–28 April, Laxenburg, Austria
The United Nations University (UNU) is organizing a conference on "The Sustainable Future of the Global System" to take place in October 1995 in Tokyo. This workshop, held at IIASA, facilitated presentation and discussion of preliminary drafts of conference participants' papers.
Contact: *Jill Jäger*

Expert Group Meeting on Population Estimates and Projections in the Arab Countries
10–14 June, Cairo, Egypt
Some 25 representatives of the statistical offices in their countries participated in this meeting, jointly organized by the Population Division of the UN Economic and Social Commission for Western Asia (UNESCWA), and IIASA's Population Project. Project members contributed findings on the demography of Northern Africa and theoretical aspects of the scenario approach for alternative population projections developed at IIASA, with applications to the Sudan, Egypt and Tunisia.
Contact: *Hassan Musa Yousif*

Nonsmooth and Discontinuous Optimization and Applications
12–17 June, Laxenburg, Austria
Some 20 experts from IIASA and other leading research institutes and universities from around the world discussed the latest theoretical and applied developments in the field of nonsmooth and discontinuous optimization, including new decomposition methods with application to problems of decision making under uncertainty.
Contact: *Andrzej Ruszczyński*

International Energy Workshop
20–22 June, Laxenburg, Austria
The 1995 International Energy Workshop—jointly organized by IIASA and Stanford University in California, USA—brought together more than 100 international energy experts. They discussed issues such as global energy projections, non-fossil primary energy sources, energy developments in Eastern Europe and in countries of the former Soviet Union, and policy issues in greenhouse gass mitigation and the regional distribution of costs and benefits.
Contact: *Leo Schrattenholzer*

Impediments to Exports in Small Transition Economies
29 June–1 July, Laxenburg, Austria
Participants focused on problems of internal and external origin of exports, a crucial issue for small countries of Central and Eastern Europe. Eight country studies and three topical studies were discussed, each specially prepared for this research effort. Papers and the case studies will be edited and published in two separate volumes.
Contact: *János Gács*

Evaluation of Ukraine's GATT/WTO Membership and Alternatives
2–4 July, Laxenburg, Austria
IIASA hosted this workshop, organized by the Ukraine Ministry of Foreign Economic Relations and the Economic Transition and Integration Project. Topics discussed included a review of GATT/WTO provisions and their impact on current economic policy in Ukraine and an exploration of regional trade regimes which might involve the Ukraine.
Contact: *Merton J. Peck, János Gács*

Russian Applied Research and Development—Its Present State and Future Promise
13–15 July, Laxenburg, Austria
This meeting, the first in a planned series aimed at addressing issues of restructuring applied research and development (R&D) in Russia focused on the general trends in Russian R&D, institutional changes, the role of enterprises in innovation, conversion of military R&D and integration of Russian R&D into the international economy. The 20 experts also explored the possibility of drafting a comprehensive report for future wide dissemination of research results.
Contact: *Leonid Gokhberg*

Dynamics and Control
17–20 July, Sopron, Hungary
The 8th International Workshop on Dynamics and Control was organized jointly by IIASA's Dynamic Systems Project and the Hungarian Committee for Applied Systems Analysis, and brought together some 20 international participants. The meeting focused on, among other topics, models for economical and biological dynamics, differential and evolutionary games and the qualitative analysis of dynamics. The publication of a proceedings volume is planned.
Contact: *Arkadii Kryazhimskii*

New Publications

The following reports are now available for US $10 each. For payment by Visa or Mastercard, please send the number of your credit card, its expiration date, and a copy of your signature to IIASA Publications. A complete publications list and ordering form is on the WWW at **http://www.iiasa.ac.at**

"Emission Trading in Europe with an Exchange Rate"
G. Klaassen, F.R. Forsund, M. Amann, RR-95-002, January 1995
Reprinted from *Environmental and Resource Economics* 4:305-330, 1994.

"Neglected Dimensions of Global Land-Use Change: Reflections and Data"
G. Heilig, RR-95-003, April 1995
Reprinted from *Population and Development Review*, Volume 20, Number 4, December 1994.

"Anthropological Invariants in Travel Behavior"
C. Marchetti, RR-95-004, May 1995
Reprinted from *Technological Forecasting and Social Change*, Volume 47, Number 1, September 1994.

Research Grants

From April to August 1995, IIASA has received research grants from the following institutions:

- The Alfred P. Sloan Foundation, USA
- The Austrian Federal Ministry for the Environment and the United Kingdom Department of the Environment
- The Austrian Ministry of Science, Research and the Arts
- The Darden Graduate School of Business Administration at the University of Virginia, USA
- The Directorate-General for External Economic Relations of the Commission of the European Union
- The Electric Power Research Institute in Palo Alto, USA
- The French Government Collaborative Fund
- Gary Bull and Associates, Canada
- The Netherlands Organization for Scientific Research (NWO)
- Repap Enterprises, Inc., Canada
- The Swedish Council for Planning and Coordination of Research (FRN)

In Memoriam

Professor **Jeffrey Z. Rubin**, member of IIASA's Processes of International Negotiations' Steering Committee from 1988 to 1995, died June 3, 1995.

Professor **Alec M. Lee**, Leader of IIASA's Management and Technology Area from May 1980 to November 1982, died June 21, 1995.

Appointments

Miguel Lechuga (Mexico), from the Universidad Nacional Autónoma de México (UNAM), has joined the Institute as the first recipient of the Luis Donaldo Colosio Fellowship.

Yasumasa Fujii (Japan), a former IIASA Young Scientists Summer Program participant in 1990 and recipient of the IIASA 1990 Peccei Award, from the Division of Electrical and Computer Engineering, Yokohama National University, has joined the Environmentally Compatible Energy Strategies Project.

Alexandre Bim (Russia), from the Russian Privatization Center, and

Leonid Gokhberg (Russia), from the Center for Science Research and Statistics (CSRS), Ministry of Science and Technological Policy, and the Russian Academy of Sciences, have joined the Economic Transition and Integration Project.

Kazuhiko Takemoto (Japan), from the Global Environment Research Division, Japan Environment Agency, has joined the Methodology of Decision Analysis Project.

Gabriele Doblhammer-Reiter (Austria), from the United Nations Center for Human Settlements (UNCHS) in Nairobi, Kenya has joined the Population, Development and Environment Project.

Gerald Silverberg (USA), from the Maastricht Economic Research Institute on Innovation and Technology (MERIT), University of Limburg, Netherlands, and

Marco Valente (Italy), from the University of Manchester, UK, have joined the Systems Analysis of Technological and Economic Dynamics Project.

Barbara Lence (USA), from the Department of Civil and Geological Engineering, University of Manitoba, has joined the Water Resources Project.

Award

On July 14, Professor Wolf Häfele, Scientific Director of the Research Center Rossendorf in Dresden, received the Honorary Doctorate in Economics from the Technical Institute of the University of Dresden.
From 1973 to 1981, Professor Häfele was IIASA Deputy Director and Leader of the Energy Program. Professor Häfele was Vice-Chairman of the IIASA Council and member of the Executive and Program Committees until 1994. He was also Chairman of the German National Member Organization in IIASA from 1984 to 1994.

IIASA National Member Organizations

Austria
The Austrian Academy of Sciences

Bulgaria
The National Committee for Applied Systems Analysis and Management

Canada
The Canadian Committee for IIASA

Czech Republic
The Czech Committee for IIASA

Finland
The Finnish Committee for IIASA

Germany
The Association for the Advancement of IIASA

Hungary
The Hungarian Committee for Applied Systems Analysis

Italy
Italian National Member Organization-in the process of reorganization

Japan
The Japan Committee for IIASA

Kazakhstan
The National Academy of Sciences

Netherlands
The Netherlands Organization for Scientific Research (NWO)

Poland
The Polish Academy of Sciences

Russia
The Russian Academy of Sciences

Slovak Republic
The Center for Strategic Studies

Sweden
The Swedish Council for Planning and Coordination of Research (FRN)

Ukraine
The Ukrainian Academy of Sciences

United States of America
The American Academy of Arts and Sciences

FURTHER INFORMATION:

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